Technology Interchange Meeting

L3 Communications West

NASA Glenn Research Center

10 February 2011

Salt Lake City, Utah

Outline

- NASA GRC Interests from L3
  - UAVs in the National Airspace System (NAS)
  - UAV link and network security (Civil and Military)
  - UAV Network (Civil and Military)
  - Collaboration on Layer-2 triggers
  - Possible Teaming
    - Earth Science Technology Office, Others
      - ESTO's solicitation will be for onboard processing and data mining
- Overview of UAV Data Delivery Project
  - Communications Architectures
    - Current and Future Scenarios
    - Mobile Communications
    - Store-Carry-Forward Networking
      - Delay Tolerant Networking (DTN)
  - Rate-Based Transport Protocols for high speed, large volume data delivery
  - Layer-2 Triggers

UAV Security

- How are the radio links and networks secured for command and control and payloads?
  - Bulk encryption at link layer?
  - Network Layer?
  - Application Layer?

UAV Network

- Are the payload and command and control treated differently?
- Is there direct communication (delivery of payload information) to the warfighter?
  - If not, will there be in the future?
- Is the any Tip and Queue being performed
  - (i.e. UAV triggers space sensor or visa versa)
  - Any interest in embedded virtual mission operations in the UAV network or onboard the UAV?
- Is all communication local within the area of operations or do you see the need for network mobility?
  - Do you need to handle network mobility currently?
  - If so, how are you doing this?
  - If not, do you foresee the need to handle this in the future?

Cognitive Networks / Cognitive Radios

- Is L3 just looking at Cognitive Radios and/or Cognitive networking?
- What is your Concept of Operations?
  - Is control in-band or out-of-band (separate radio channel for control only)?
  - Do you assume some discovery/recovery algorithm to find and maintain sync?
  - Are you addressing multi-homing issues?

Operational Responsive Space

- What is your Concept of Operations?
- Do you have some architectural concepts
- What do you see as the requirements and applications?
- Are you working with anyone at ORS?
  - If so, have they articulated what it is they are really trying to do?
  - Has ORS expressed any desire for fractionated spacecraft (DARPA F6 program)?

Real-Time and Store-and-Forward Delivery of Unmanned Airborne Vehicle Sensor Data

PI: Will Ivancic/GRC

Co-PI: Don Sullivan/ARC

PROJECT OVERVIEW

Real-Time and Store-and-Forward Delivery of Unmanned Airborne Vehicle (UAV) Sensor Data

PI: Will Ivancic/GRC

Objectives

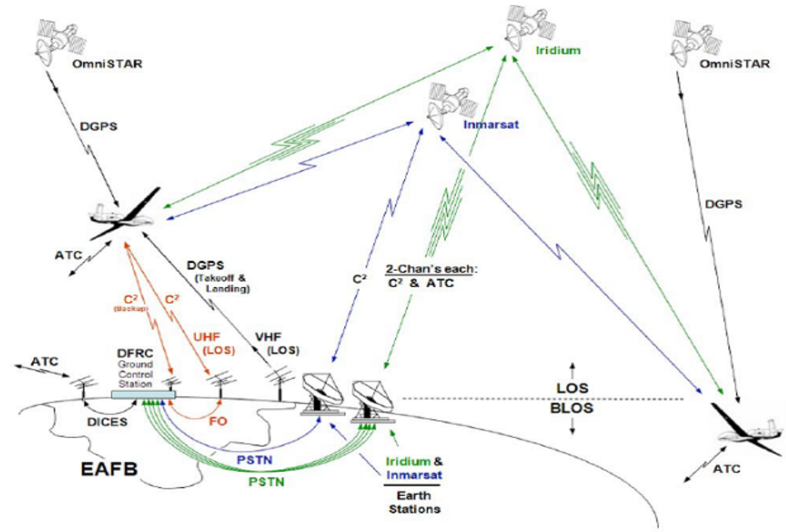
- Develop and deploy an unmanned airborne vehicle (UAV) mobile communication architecture based on Internet technologies
- Improve the data throughput by developing and deploying technologies that enable the efficient use of the available communications links. Such technologies may include:
  - Development of store-and-forward techniques and protocols
  - Improvements to the Saratoga transport protocol (implementing a rate-based feature and congestion control)
  - Development of a protocol that advertises link properties from modem to router

Approach

- Collaborate with ARC UAV team and its satellite communications service providers to develop requirements and deploy advanced bandwidth efficient, reliable file transport protocols for the Global Hawk UAV
- Collaborate with appropriate router and radio manufacturers to develop a rate-based implementation of Saratoga and a modem link-property advertisement protocol
- Conduct integrated tests of the architecture and protocols using flight sensor data as a part of the GloPac, GRIP and future flight missions

Co-I's/Partners

Don Sullivan/ARC



Global Hawk Command and Control Network

Key Milestones

Develop UAV communications architecture	12/09 ✓
Rate-based transport protocol initial deployment	2/10 ✓
Rate-based Saratoga Version 1 for single hop store and forward	6/11 ☜
Develop radio-to-router Layer-2 trigger protocol	3/12
Conduct integrated demonstration	5/12

TRL_{in} = 4 $TRL_{current}$ = 4 (Transport Protocol)

TRL_{in} = 2 $TRL_{current}$ = 2 (Layer-2 Trigger)

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Revised Goals

- Improve the data throughput and utilization of current UAV remote sensing by developing and deploying technologies that enable efficient use of the available communications links.
- Develop and deploy a communication protocols based on Internet Technologies that could be utilized on the Global Hawk Unmanned Arial Vehicle (UAV) for atmospheric research.

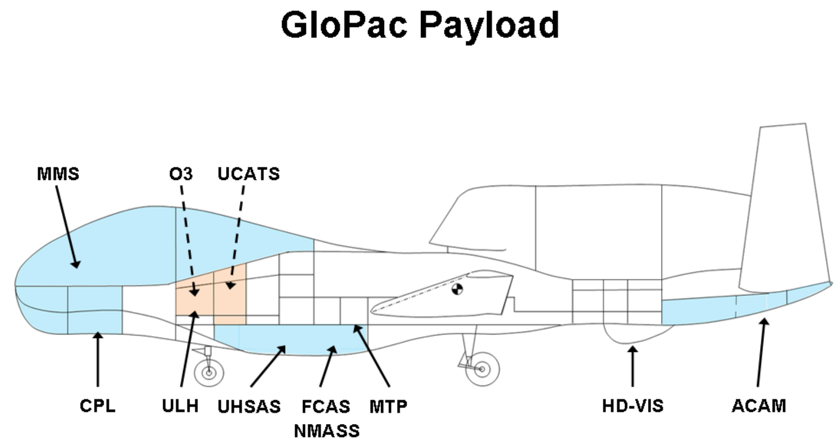
(Network Mobility and Delay Tolerant Networking currently do not appear to be required for NASA's UAV deployments.)

Work Items

- GRC
  - Mobile communication architecture,
  - Rate-based transport protocol and/or techniques
  - Store-and-forward protocols
    - Examination of the NASA Global Hawk deployments do not require multi-hop store and forward protocols such as DTN
  - Layer-2 triggers.
- Ames
  - Development and testing of software for the command and control of the sensor packages onboard the Global Hawk
  - Integration of GRC developed communication software with command and control Software

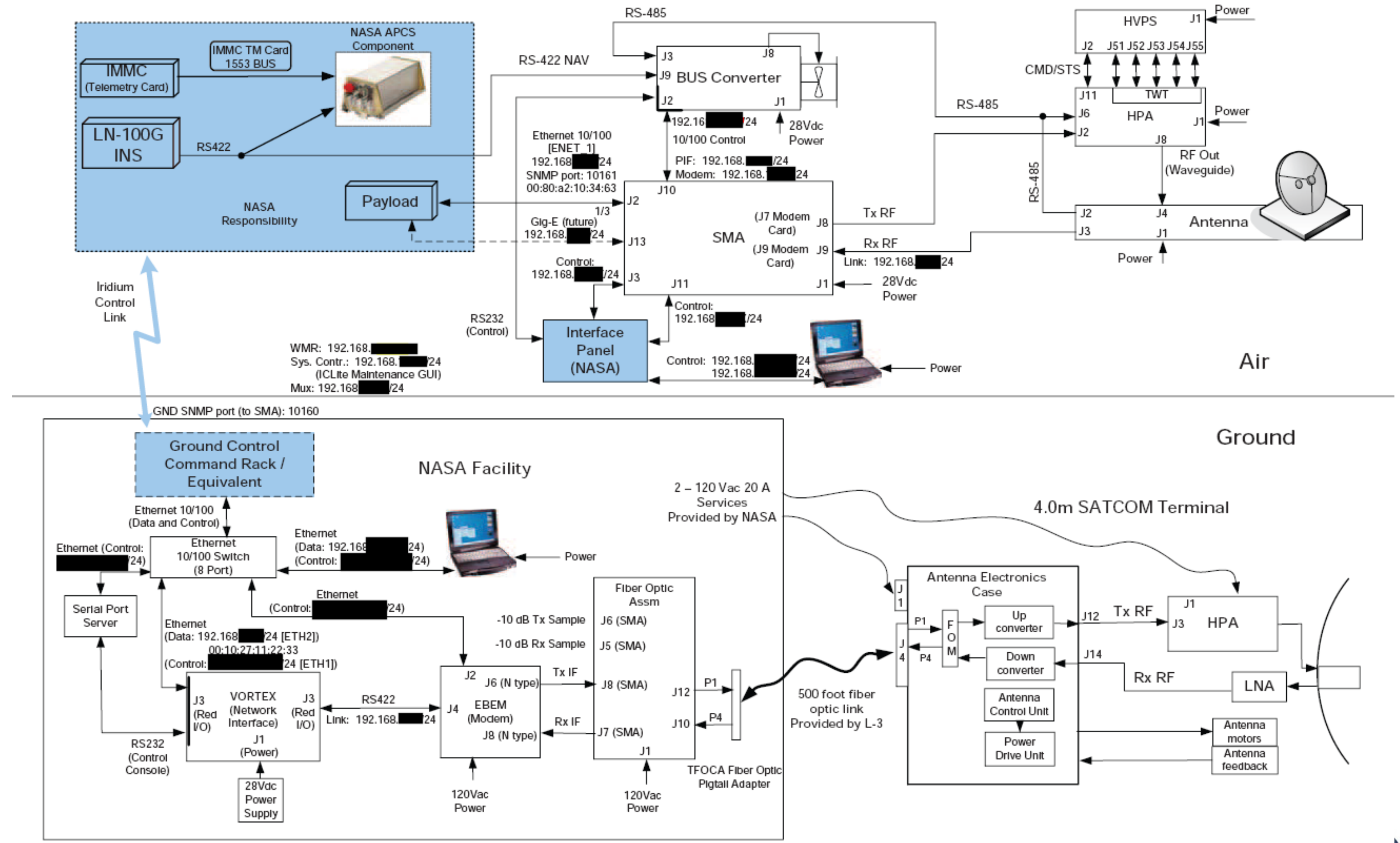
COMMUNICATIONS ARCHITECTURES

Global Hawk



GloPac Payload
MMS
O3
UCATS
CPL
ULH
UHSAS
FCAS
NMASS
MTP
HD-VIS
ACAM

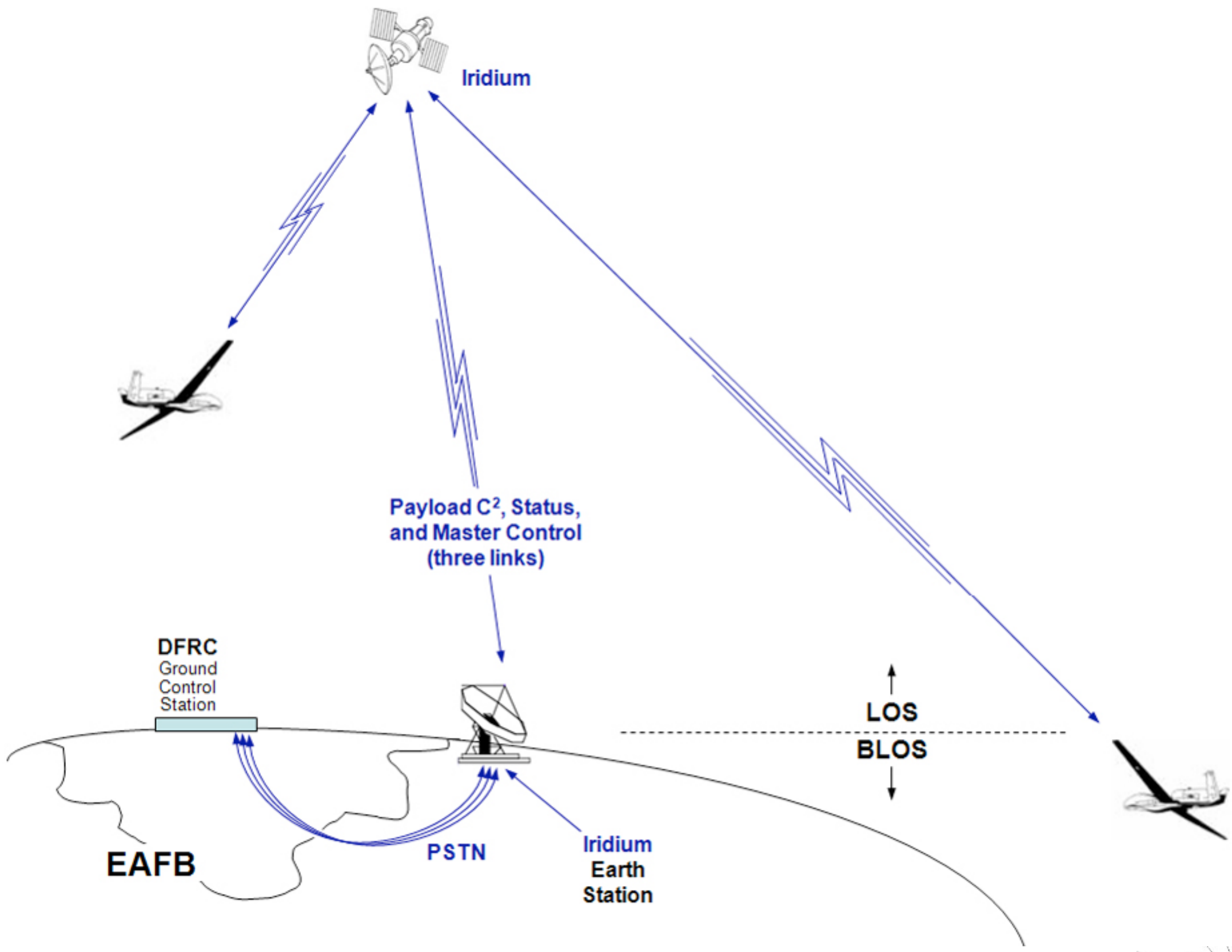
Global Hawk Communication System Block Diagram



Command and Control Communications

- Aircraft Command and Control (C2) communications.
  - LOS -- 2 UHF/LOS links.
  - BLOS -- 2 Iridium links and 1 Inmarsat link.
    - INMARSAT is a GEO satellite and does not cover the poles
- Air Traffic Control communications.
  - LOS -- VHF/UHF radios at Dryden.
  - BLOS -- 2 Iridium links with aircraft.
- Payload C2 and Status communications.
  - 5+ Iridium links.
  - Investigate for potential to use this link for Metadata and Prioritized Queuing of payload data.

Initial Payload C2 and Status Communications Architecture



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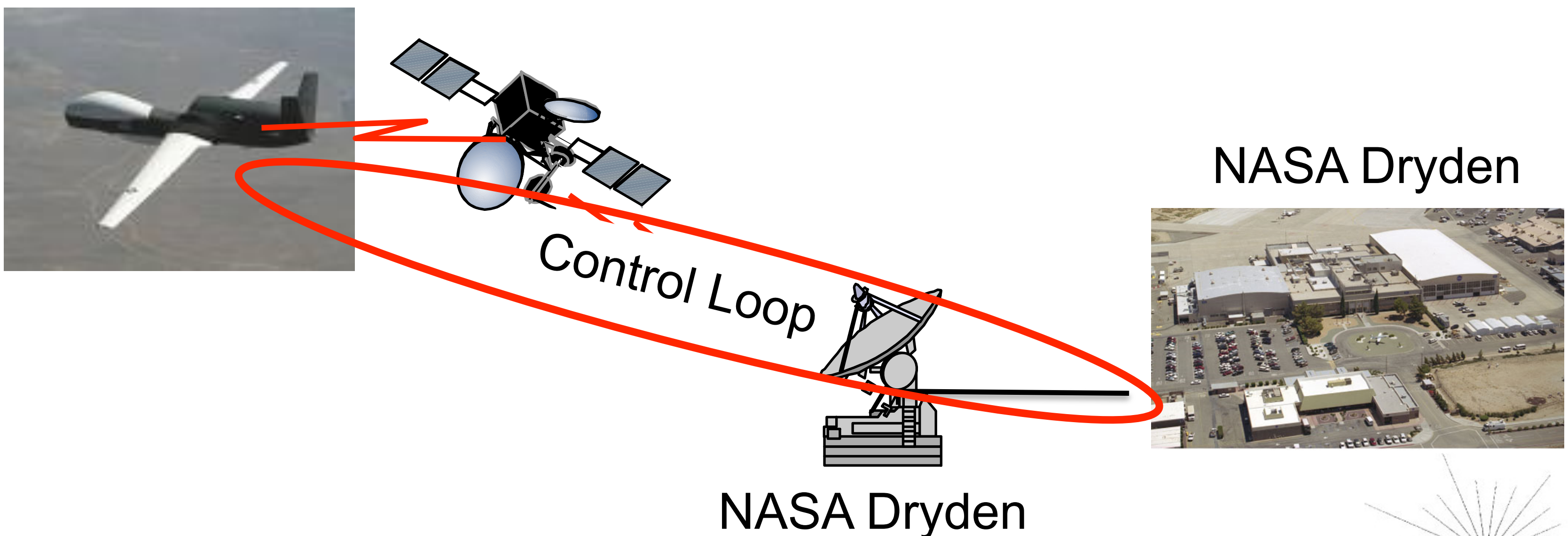
Current Communication Architecture

- Global Hawk ground station is located at Dryden as are the Principle Investigators
  - No multi-hop store and forward.
  - Single control loop
  - Delay is up to 600 msec round trip time due to Geostationary Satellite delay.



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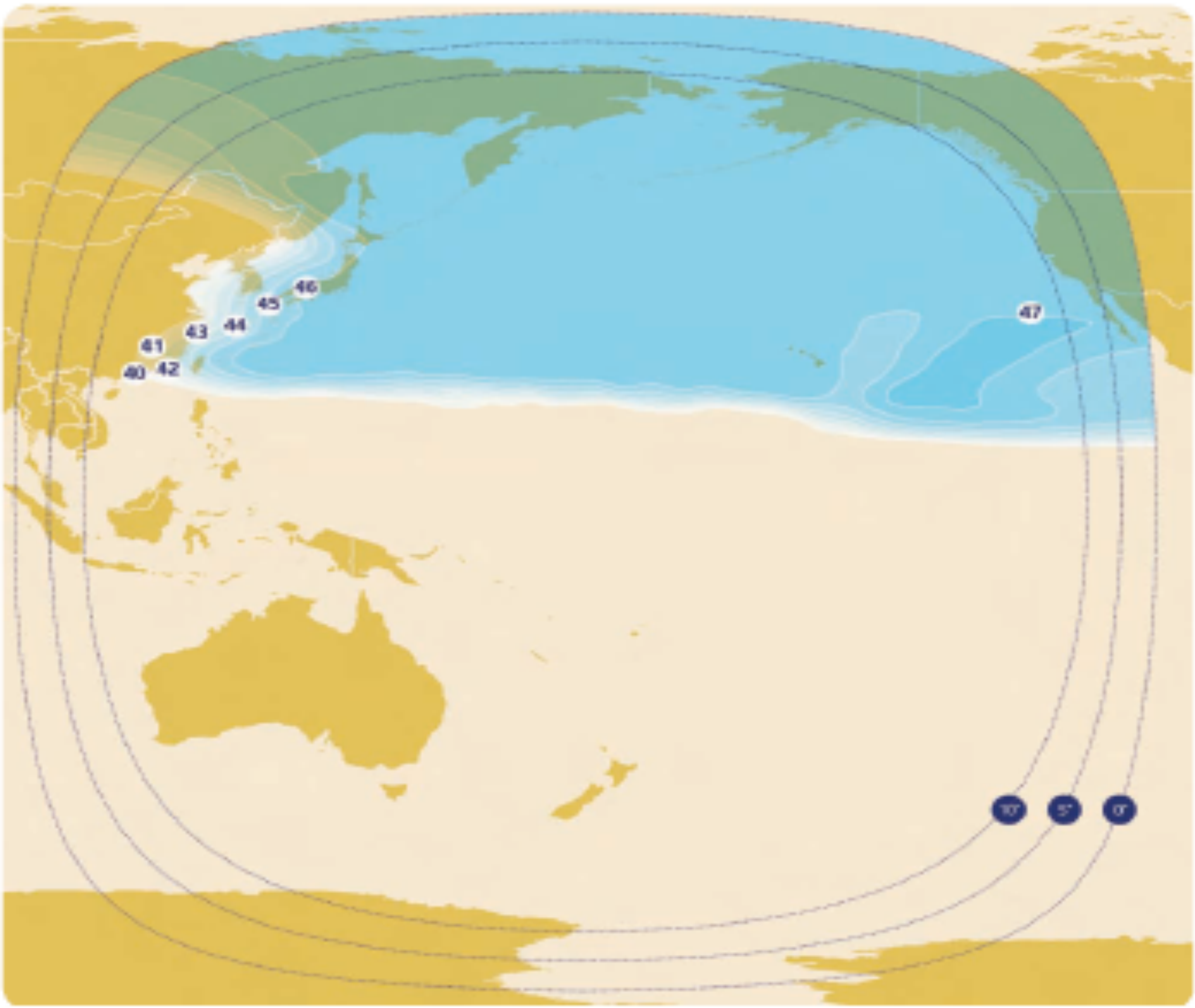
GE-23 Coverage

North Pacific Ku-band Beam



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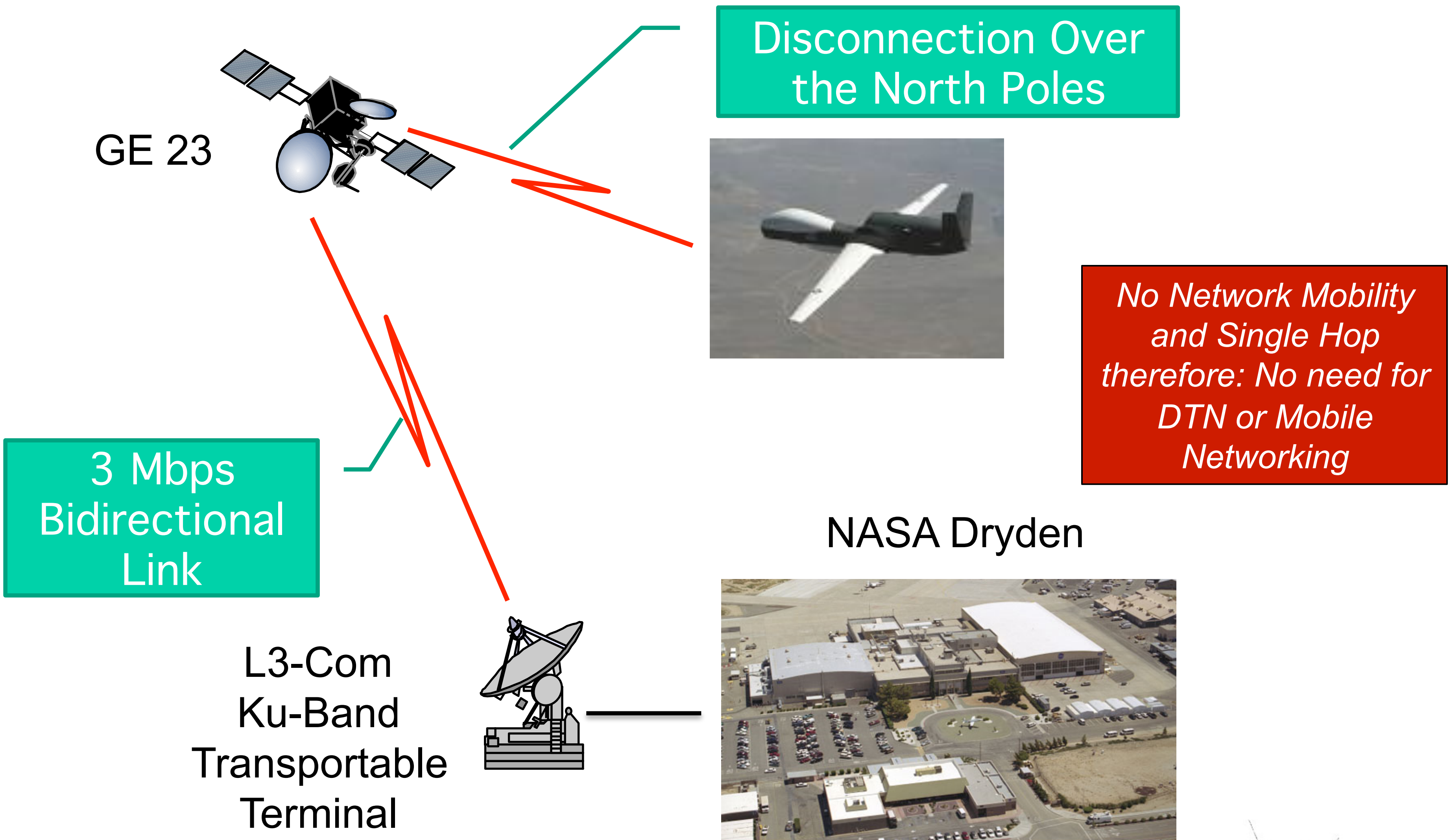
GloPac Communication Network



Global Hawk Control Room at Dryden

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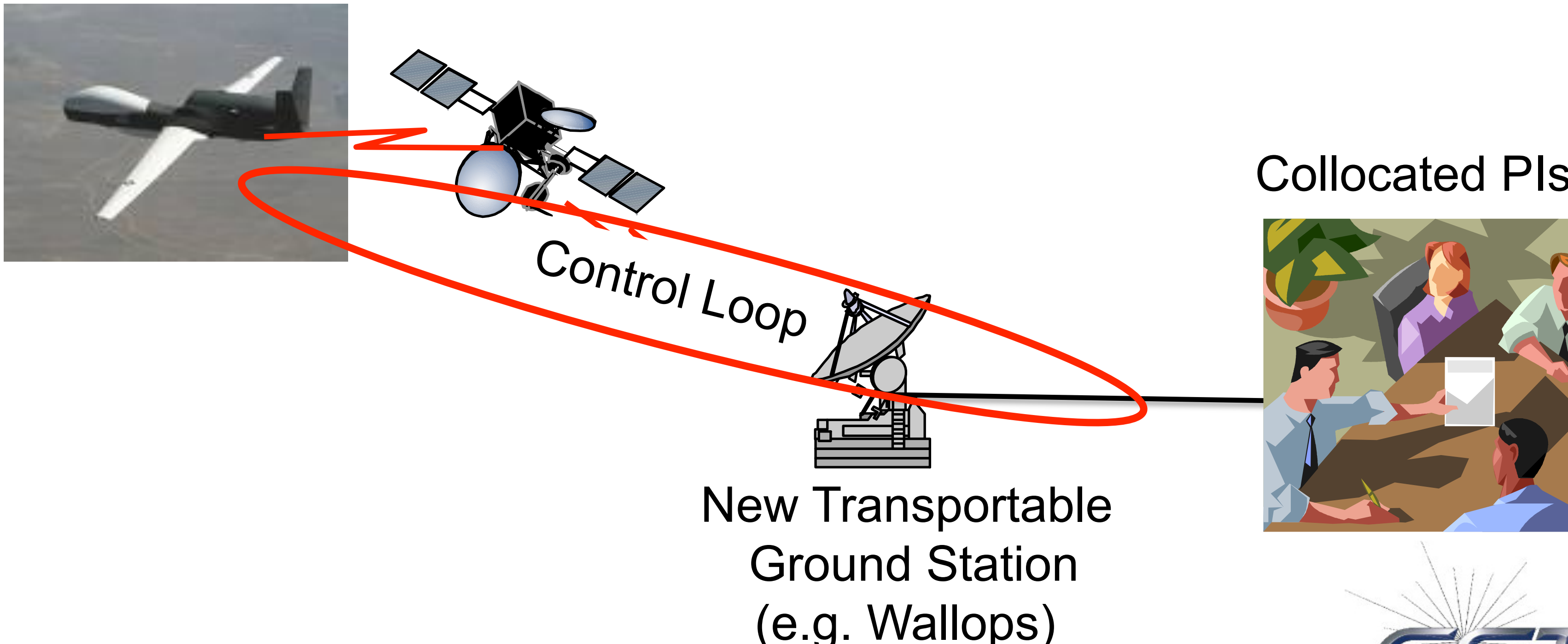
Next Mission
(Greenland / Iceland)

- Global Hawk ground station is located at near mission and Pis are collocated near ground station.
  - No multi-hop store and forward.
  - Delay is up to 600 msec round trip time due to Geostationary Satellite delay.
  - Single control loop



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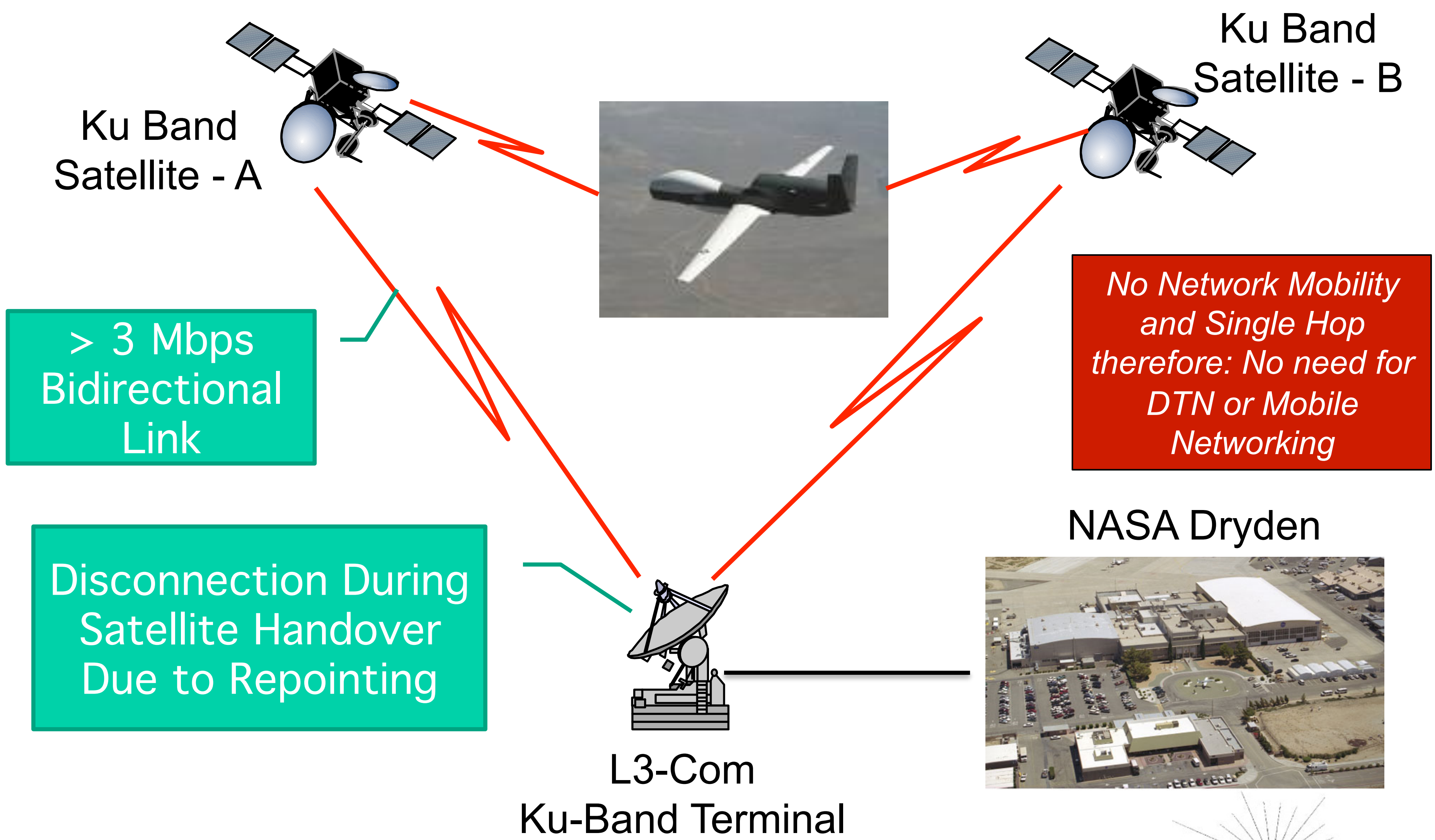
GRIP Communication Network



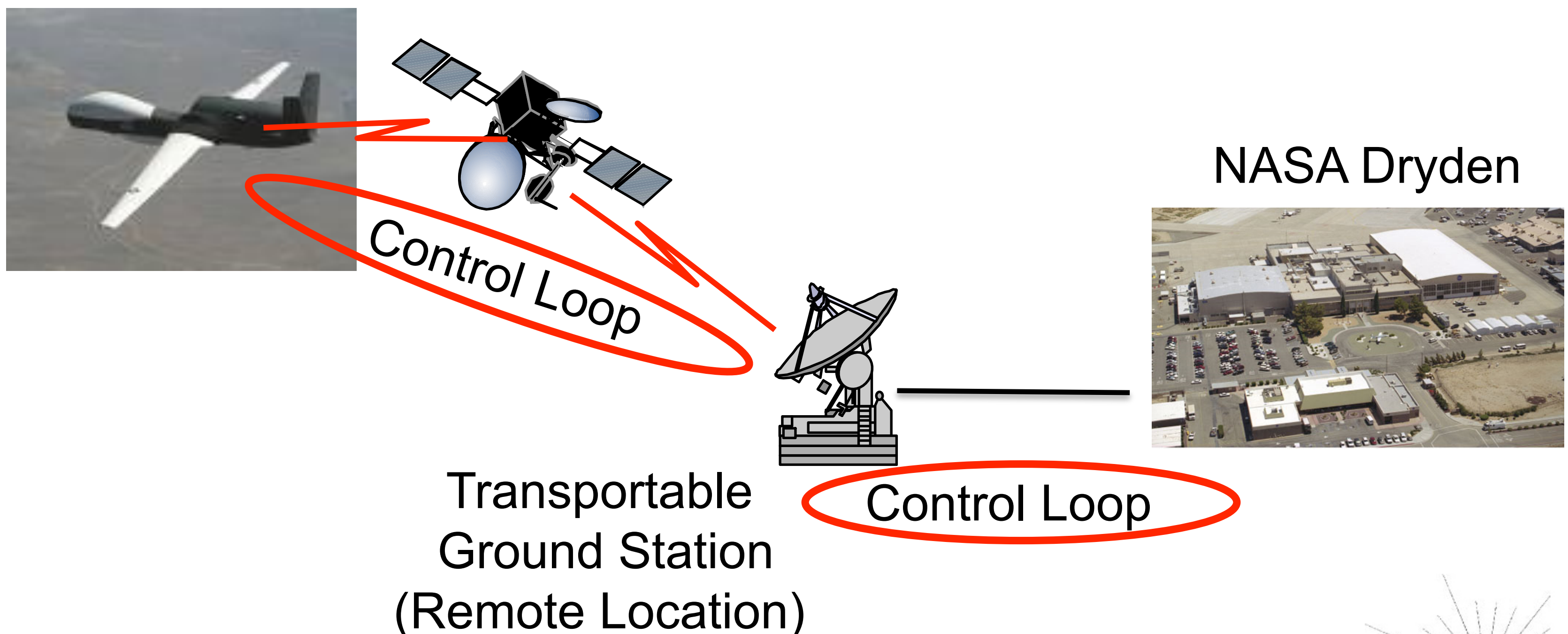
Collocated Pis

- Pros
  - Eases coordination between PIs as well as between PIs and aircraft controllers
  - Ensures commitment
  - Builds teams and teamwork
  - Cross pollination of ideas
  - Collocated with Global Hawk ground base provides access to payload for pre-flight checkout.
    - But, that probably does not have to be everybody and probably does not have to be at the ground station.
- Cons
  - Travel time
  - Travel costs
  - Away from home

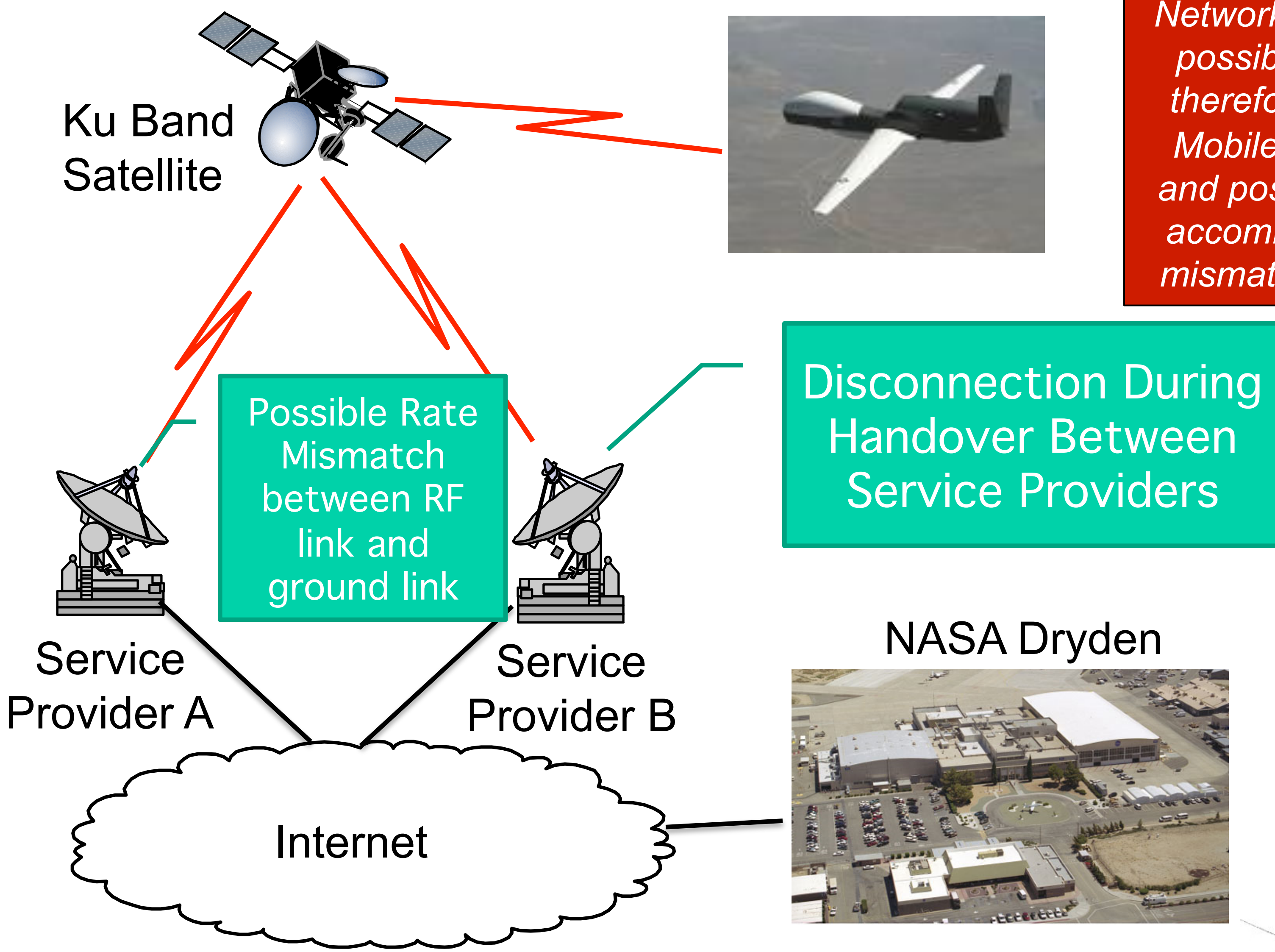
The technology exists to allow Principle Investigators to operate from remote locations.

Possible Operations Scenario

- Aircraft Operators and Principle Investigators located at Dryden or remote
  - Some PIs with payload
- Ground Station Remote
  - Simple two-stage store and forward.



Future Communication Network



Network Mobility and possible multi-hop therefore: Need for Mobile Networking and possible DTN to accommodate rate-mismatch problems.

MOBILE COMMUNICATIONS ARCHITECTURE

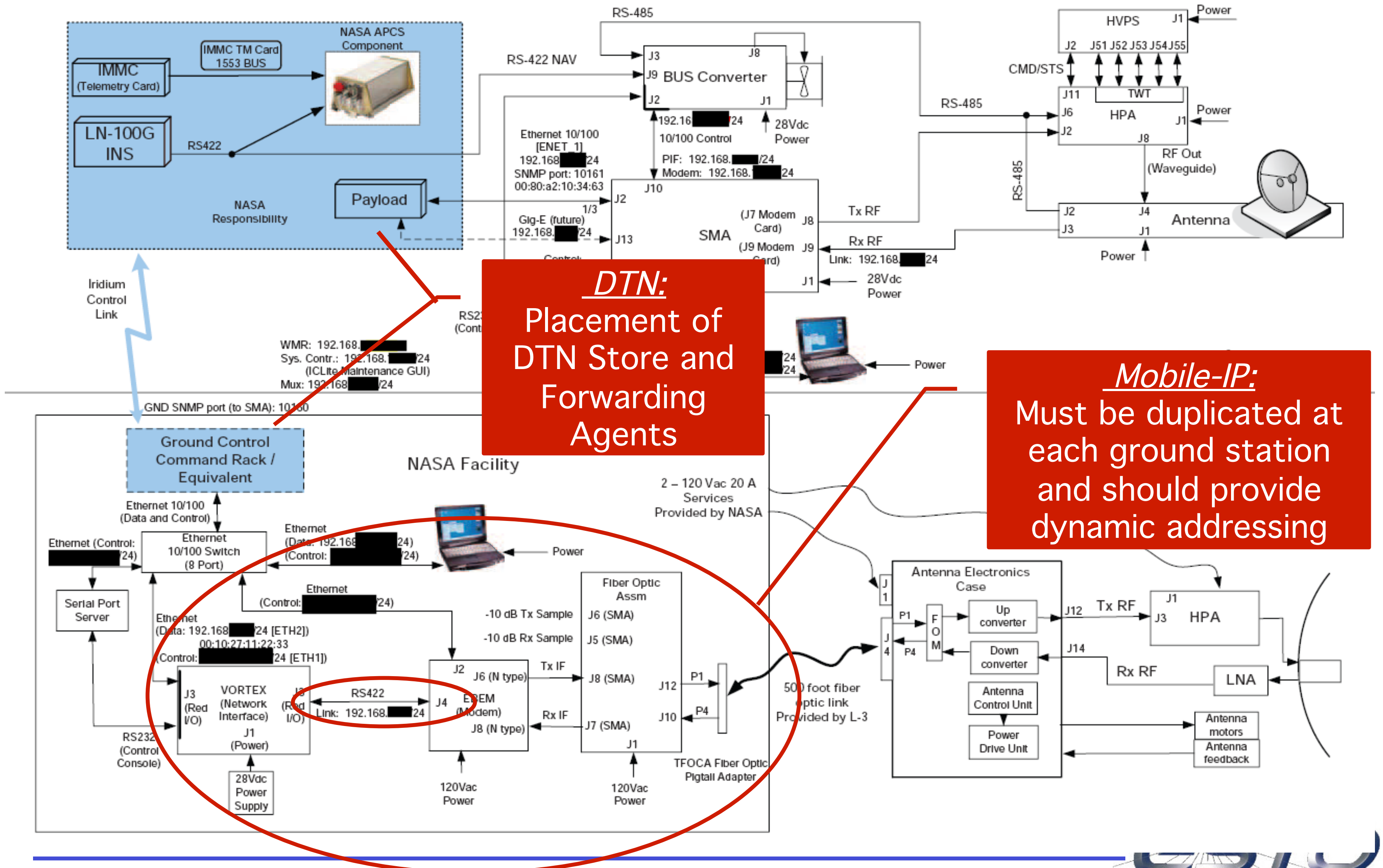
Mobile Communications Architecture

- Requirements
  - Provides connectivity via the Internet
    - Via infrastructure under NASA control
      - Initial Deployment for GLOPAC
      - Also current architecture for GRIP
    - Via infrastructure that may be owned and operated by third parties.
      - Possible architecture for future missions
  - Addresses security needs
- Possible solutions
  - Store and Forward over Mobile-IP
    - Advantage is Mobile-IP registrations provide a trigger to the transport protocol that connectivity has been established
  - Direct Store and Forward
    - Issue – how to determine connectivity is established?
      - Saratoga provides such functionality

Technical Issues

- Mobile-IP
  - Custom Global Hawk payload design requires “buy in” from communication system design team to implement mobile-IP or at least dynamic addressing on Space/Ground link.
- DTN
  - Cannot assume control of Service Provider clocks
    - Requires modification to DTN to solve time-sync problem
    - Issue is being worked in Internet Research Task Force (IRTF)
      - This is a recent resolution decided in March 2010
  - Current DTN has no CRC check requirement
    - Current solution is to use Bundle Security Protocols Bundle Confidentiality Block with known shared keys.
  - Expired proposal to use “Reliability” Extension Block to ensure point-to-point reliability.

Global Hawk Communication System Block Diagram



DTN:
Placement of DTN Store and Forwarding Agents

Mobile-IP:
Must be duplicated at each ground station and should provide dynamic addressing

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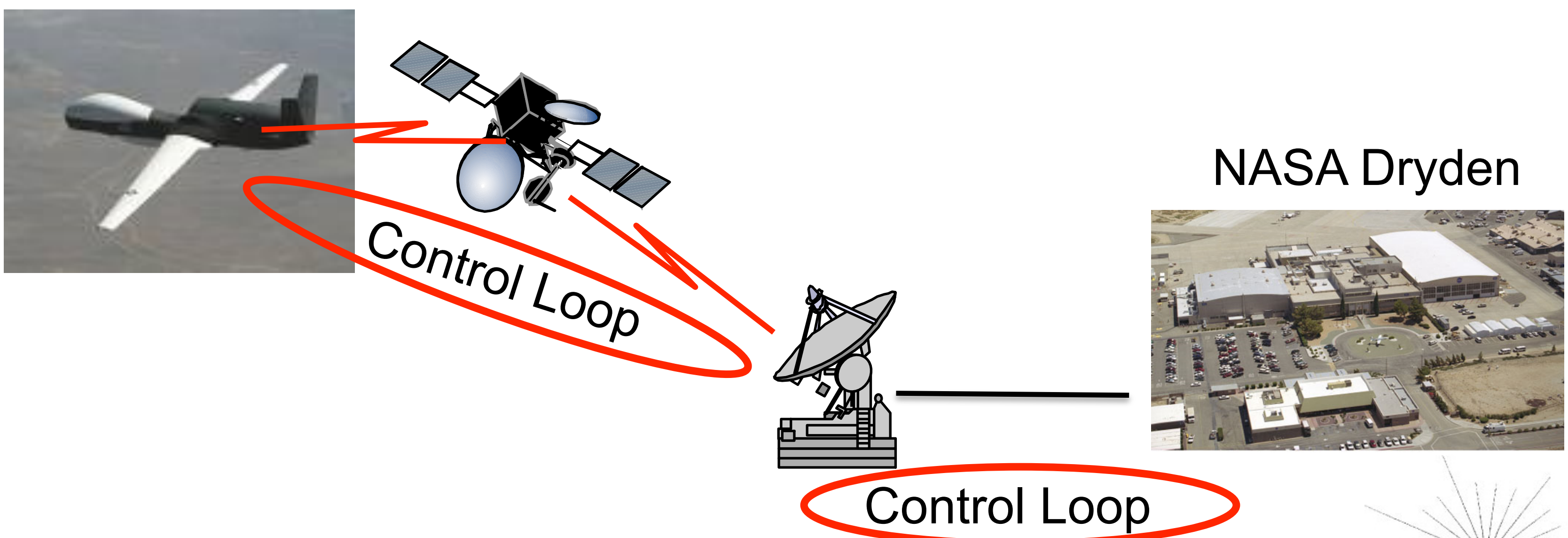
STORE AND FORWARD PROTOCOLS

Why Store and Forward

- Global Hawk has large periods of disconnection from the network and needs to store data during disconnection and transmit data during times of connectivity
- Store and forward can break control loops
  - Allows for link by link transport protocol optimization.



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RATE-BASED TRANSPORT PROTOCOL

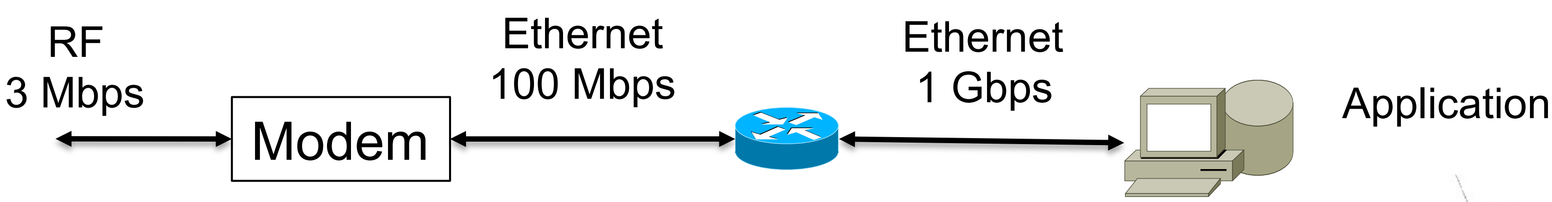
Reliable Rate-Based Protocols

- Saratoga version 1
  - Saratoga version 0 implemented by Surrey Satellite Technology Limited for simple file transfer over highly asymmetric links
    - Used to transmit images for satellite to ground
    - Proven and operational
    - Full utilization of the RF channel
  - Saratoga version 1 is and Internet Draft that include improvements include unidirectional transfer and use of UDPlite
- Negative Acknowledgement (NACK) - Oriented Reliable Multicast (NORM)Transport Protocol
  - Uses a selective, negative acknowledgment mechanism for transport reliability
  - Leverages the use of forward error correction (FEC) repair and other IETF Reliable Multicast Transport (RMT) building blocks
  - Can operate in unicast mode
  - Used on Naval Research Lab's MidStar-1 Satellite for unidirectional link file transfer
- CCSDS File Delivery Protocol (CFDP) – Class 2
  - Class 2 provides for the reliable delivery of bounded or unbounded data files from the source to the destination.
- CFDP – Class 1 over DTN over LTP over IP
  - CFDP provides the file transfer application while LTP Provides the reliability

LAYER-2 TRIGGERS

Smart Modems

- Modem's transmitting and receiving link rates can be varied over time due to the following:
  - Adaptive coding
  - Changes in Modulation to suit the channel characteristics.
  - Changes in transmission rate to suit the channel characteristics
- Rate mismatch between RF link local area network.
  - Serial connections are less of a problem as clocks can be controlled by modem (at least the receiving clock)
  - Ethernet connections are becoming standard and result in rate mismatch between the LAN interface and the RF link.



Issue / Problem

- To condition traffic and get the most out of the modem's link capacity, applications need to know the modem's link conditions.
  - Figure 1 corresponds to existing commercial imaging satellites
  - Figure 2 is more generic
- Desire is to have a standard method for the application to understand the link conditions and adjust
  - Link Up/Down
  - Link Unreliable
  - Data Rates

Figure 1

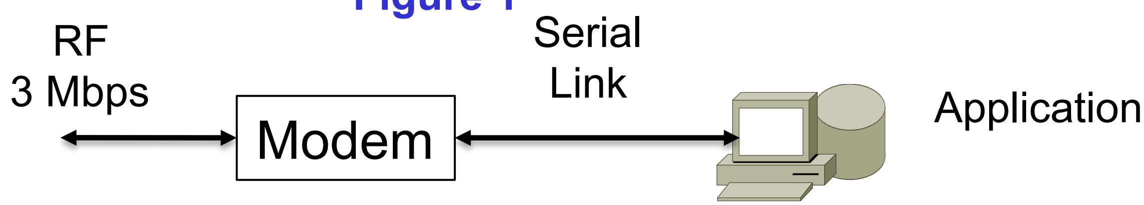
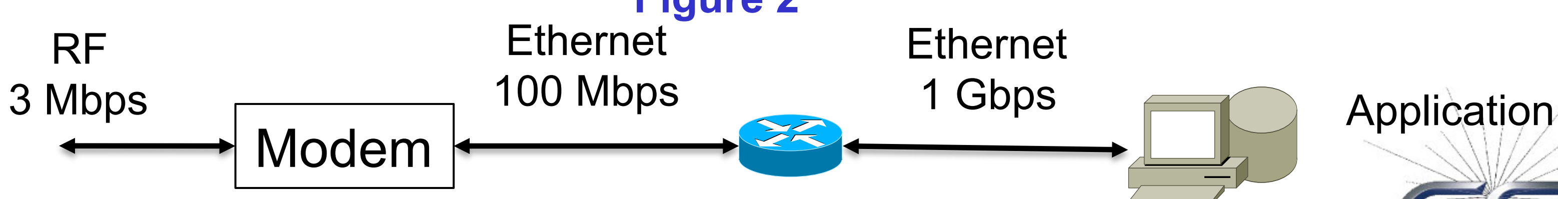


Figure 2



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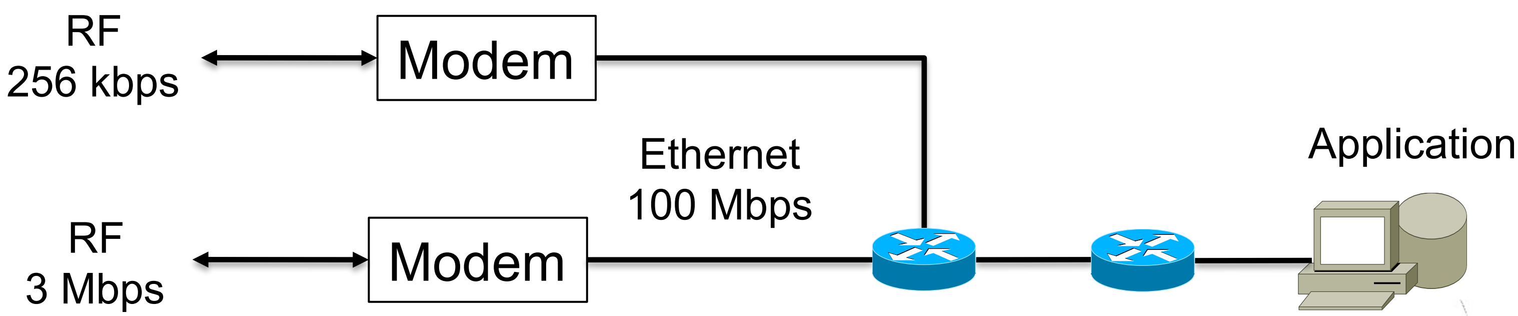
Solution

- Develop a standard protocol that provides link status conditions
  - Probably should be able to provide wide area network (WAN) radio reachback link status to applications that may be multiple hops away.
- Uses
  - Applications can adjust to link state
  - Route Optimization
    - Useful for multi-homed systems



Strategy

- Release public request for participation to radio system providers
  - ViaSat, Raytheon, Honeywell, Harris and L3 are potential participants.
  - Possible work with Cisco
- RFC-5578, PPP over Ethernet (PPPoE) Extensions for Credit Flow and Link Metrics
  - Informative Document
  - Similar Idea, but very complex with to many parameters that cannot be set well.
  - Dan Shell (former Cisco) and Will Ivancic (NASA GRC) experimented with Harris $200K plus MANET radios
- Use expired Internet Draft "Link properties advertisement from modem to router" as a starting point.
- Demonstrate usability in C++ implementation of Saratoga
  - Listen for on multicast channel to set rate-limit
  - Can test in Global Hawk Protocol Testbed.

Backup

DTN Bundling Fixes

- Add ability to process bundle using relative time
  - DTN currently requires network synchronization to some fraction of the smallest lifetime bundle processed for the protocol to work. This can be non-trivial.
  - Numerous problems with synchronization have been identified during field trials
- Add simple CRC check capability in an extension block or the header
  - Current No checksum is included in the basic DTN Bundle Protocol
    - It is not possible to verify that bundles have been either forwarded or passed through convergence layers without error.
  - Current solution is to use reliability-only Checksum Ciphersuites
    - Requires the Bundle Security Specification be implemented
  - Previously proposed solution is to have reliability implemented as its own extension block
    - Separates reliability from security
    - Does not require node with limited processing power to implement security

DTN Bundle Age Block for Expiration without UTC
draft-irtf-dtnrg-bundle-age-block-00

- A decision was made at IETF 77 held in Anaheim, California that an extension block option would be used to enable DTN to operate within systems that cannot guarantee accurate Universal Time Code synchronization.
- Authors: D. Brown - Raytheon BBN Technologies, Stephen Farrell - Trinity College Dublin, ***Scott Burleigh - Jet Propulsion Laboratory***

Abstract: As originally specified, [RFC5050] presumes that any DTN node will have access to accurate real world time. Experience has shown that there are devices and networks where accurate real world time is difficult or impossible to consistently obtain.

This draft proposes an extension block that contains the current age of a bundle in order to support bundle expiration for nodes and networks that have faulty, intermittent, or no notion of the real world time. Bundle age may be used to expire bundles by a Bundle Protocol Agent which does not have access to accurate real world time. The Age must be updated at each hop in order to maintain accuracy.

"It is strongly recommended that specification of Age at bundle inception and the processing of Age values become mandated by moving the Age value in some form into the Bundle primary block at some future time."

Store and Forward Needs a Redo

- Delay Tolerant Networking Research Group (DTNRG) at the Internet Engineering Task Force (IETF) 77th Meeting in Anaheim, CA
  - Discussion on RFC5050-bis (bis is latin for repeat or twice – second version)
    - Not enough energy
    - To early
    - Is BIS an IETF responsibility
    - IETF would probably not move RFC5050 to any standard
      - Mixes application and protocol
      - Lots of other stuff (checksums, synch, etc...)
- Current implementation is nice for research due to extension blocks and flexibility, but poorly engineered
- Current implementation does not scale
- Overly complex
  - Tries do to more than store and forward
    - i.e. secure content distribution and storage
    - An attempt at content-based routing